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LETTER

Trends in tropical tree growth: re-analyses confirm earlier findings

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In a recent Opinion article, Brienen *et al.* (2016) raise doubts about our finding that tropical tree growth has not increased during 150 years of CO_2 rise (Groenendijk *et al.*, 2015; Van Der Sleen *et al.*, 2015). They claim that our tree-ring data contain evidence for historical growth stimulation that was concealed due to failing regeneration in several species. Here we show that (i) the correction method proposed by Brienen *et al.* induces a bias towards finding positive growth trends, (ii) the results of Brienen *et al.* rest on selective removal of species from the data set, (iii) there is a simple and effective way to accommodate effects of recruitment failure by subsetting data, and (iv) the application of this method confirms our earlier findings. Thus, our results are robust to effects of recruitment failure and our conclusions remain unchanged: we find no evidence for historical growth changes in our studied tree species.

Brienen *et al.* pointed out that growth trends obtained from tree populations which lacked recruitment in recent years may contain spurious negative trends. Such negative trends are caused by a change in the distribution of slow- and fast-growing individuals in the tree-ring sample (see Figure 1 in Brienen *et al.*). The potential effect of 'recent recruitment failure' was first described by one of us (Vlam, 2014). In our pantropical tree-ring study, 8 of the 12 study species exhibited significant recruitment failure during the last 10–80 years (Table S1). In our recent work, we discussed this bias (Groenendijk *et al.*, 2015), but we did not account for it statistically as we lacked the means to quantify its strength.

Brienen *et al.* presented a randomization method to evaluate the effect of recent recruitment failure and correct for possible spurious trends. They then applied this 'shuffling method' to our data set. While their method is elegant and conceptually sound, it (i) produces spurious results, (ii) yields weak results when applied to our data set and (iii) is used by Brienen *et al.* to make unfounded inferences. First, as Brienen *et al.* pointed out, the shuffling method produces spurious positive growth trends of 0.6-0.9% per decade in test simulations (their SI Figure 3), thus overestimating growth increases in their re-analysis. Second, when applying the shuffling method to our data, only 13% and 5% of all regression slopes (a calendar year effect on growth) were significant (at $\alpha = 0.05$ and $\alpha = 0.01$, Table S2). In 71–92% of the cases, the shuffling procedure produced only weak support for recruitment failure effects, with <10% of random regressions being significant. Weak effects of recruitment failure were also demonstrated by high percentages of positive slopes in these simulations, as recruitment failure should result in negative slopes (Table S2). Together, these results thus provide little support to apply this shuffling procedure to our data. Third, Brienen *et al.* used the results of 500 random simulations to calculate 95% confidence intervals of average regression slopes to test whether these differ significantly from zero. Evidently, such inferences are flawed, as confidence intervals and *t*-test results directly depend on the number of randomization trials, which can be inflated to obtain 'significant' results. It is also disconcerting that Brienen *et al.* selectively and unnecessarily removed 3–6 species from the data set. Two removed species were potentially affected by a bias that is easily accounted for (Groenendijk *et al.*, 2015; Van Der Sleen *et al.*, 2015), and three others were removed because of recruitment failure, but for this, the shuffling method should supposedly have accounted.

We propose an effective and more straightforward method to account for the effects of recent recruitment failure, using data subsetting (Table S1). As recruitment failure only affects recent growth rates in the tree-ring data set, it suffices to remove those values prior to analysing growth trends. After data subsetting, we reran our statistical analyses. We also performed tests that accounted for the predeath slow-growth bias (Van Der

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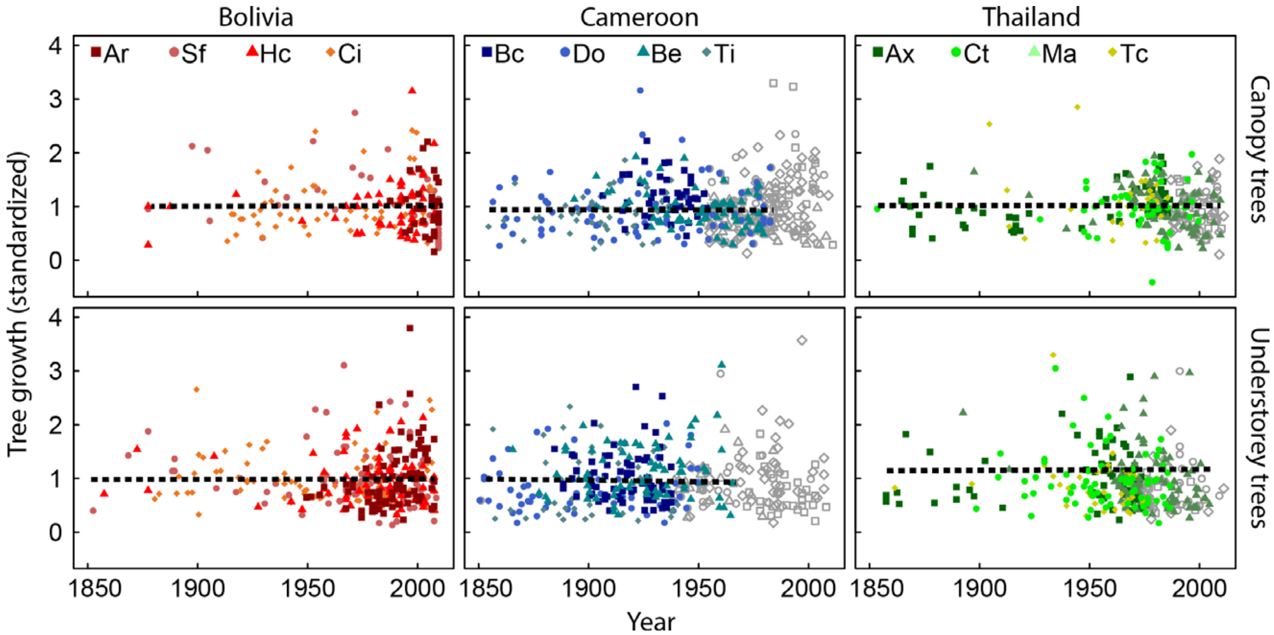

Fig. 1 Results of the re-analysis of growth trends in 12 tropical tree species after subsetting data to account for potential effects of recruitment scarcity. Data points left out of the analyses are shown as grey unfilled symbols (see Table S1). Analyses were carried out separately for canopy and understorey trees (see Table S3a). Dashed lines indicate nonsignificant growth trends per site; trends for sites combined were also not significant (Table S3). For information on methodology, see Van Der Sleen *et al.* (2015). Species codes are first letters of genus and species names (see list in Table S1). [Colour figure can be viewed at wileyonlinelibrary.com].

Sleen *et al.*, 2015) and left out one species with a potential bias that cannot be corrected for (Groenendijk *et al.*, 2015). In all three sets of re-analyses, we did not find evidence for a significant growth increase over the last 150 years (Fig. 1, Table S3).

We greatly value the effort of Brienen *et al.* to quantify the effects of recent recruitment failure on growth trends. Their work nicely illustrates the rapid methodological developments in tree-ring research. We agree that growth trends obtained from tree rings should be interpreted cautiously, but note that this is also the case for plot-derived growth trends (Bowman *et al.*, 2013; Chambers *et al.*, 2013). We conclude that tree-ring research can importantly contribute to understanding effects of global change on tropical forests (Zuidema *et al.*, 2013) because of the long time spans covered.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. A simple and effective method to account for the effect of recent recruitment failure on growth trends based on tree-ring data.
Table S2. Performance of the randomization 'shuffling' procedure proposed by Brienen *et al.* (2016).
Table S3. Re-analyses of growth trends for our 12 study species.